ScenSor
Designing the first commercial IEEE 802.15.4a chip

• Luc Darmon, Michael McLaughlin, Dries Neirynck
• IEEE Conference EILAT 2012
Introducing DecaWave
Introducing DecaWave

• DecaWave is a Fabless Semiconductor Company designing and bringing to market a family of IEEE802.15.4a compliant Integrated Wireless Transceivers called ScenSor based on Ultra Wideband Technology

• We make Integrated Wireless Transceivers, A complicated way of saying an integrated radio transmitter and receiver on the same piece of silicon

• **Our Wireless Transceivers can also Locate things.** We allow Real-Time Location Systems to reach unprecedented performance levels at consumer costs.
“The Internet of Things”

A World where anybody or anything can locate and communicate between any other person or thing, made possible by pervasive, low power, low cost, high data rate wireless transceivers.
Technology and Technical Solution
COHERENT

ULTRA-WIDEBAND

The intuitive explanation
Narrowband versus Ultra-Wideband

**Narrowband**

![Narrowband waveform](image)

**Ultra Wideband**

![Ultra Wideband waveform](image)
In the presence of noise

Narrowband with Noise

Ultra Wideband with Noise
In the presence of multipath

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Time</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Narrowband with Reflections**

- Direct Pulse
- Reflected Pulse
- Sum of the 2 Pulses

**Ultra Wideband with Reflections**

- Direct Pulse
- Reflected Pulse
- Sum of the 2 Pulses
Find the unicorn (non-coherent version)
Find the unicorn (coherent version)

Image credit: Nick Ace, Colorblind Unicorn
IEEE 802.15.4A
IEEE 802.15.4a

- IEEE Standard
- Capability
- Utility

802.15.4a

Baseline: Q1 ‘05
Completed: Q4 ‘06
Ratified: Q1 ‘07

Location, Communication, Control

up to 27 Mbps, 500m range, with location & mobility
IEEE 802.15.4a preamble

Benefit of ternary codes:

– support both coherent and non-coherent detection
– Perfect autocorrelation allows ranging
IEEE 802.15.4a Payload

- Non-coherent RX can only use position information
- Coherent RX benefits
  - Burst phase contains error correction information
  - Burst spreading code allows noise suppression
DecaWave Scensor
Technical Solution

- Low power and cost
- Superior technical solution
- Market Driver of Precision, Reliability

IEEE 802.15.4a

ultra-wide band

DecaWave

Enhanced solution built on foundations of UWB
The disruptive value of DecaWave ScenSor IC

Low power and cost  \[\rightarrow\]  DecaWave

DW delivers a chip that is superior to comparative offerings in numerous ways:

- 5 times smaller, hence cheaper and lower power
- Can locate items within 10 cm of where they are, and highly reliable
- LOS 350m, NLOS 40m, allowing it to be deployed in WLAN APs
- Can identify up to 11,000 items within a 20 meter radius
- Both One way and Two way ranging capability, hence no infrastructure required
- Very high immunity to multi path fading, allowing east installation for end user
- Avoids spectral crowding of the ISM bands, hence dove tailing with WiFi installations

DecaWave solves the problem of location specific identity indoors at ultra low cost & ultra low power
Decawave ScenSor

- Seek, Control, Execute, Network / Sense, Obey, Respond

- TSMC CMOS 90 nm
- Output up to -10 dBm
- 6 frequency bands supported from 3.5GHz to 6.5GHz
- 110kbps, 850kbps & 6.8Mbps data rates

- Decawave’s IP (patents and “know-how”) allows us to have an ultra-low complexity coherent receiver, thereby giving the benefits of superior range & precision at ultra-low power at a very cost competitive price tag.
Journey to ScenSor Full Production

MPW3 Oct 2012
- **Customer Validation:** 10 Design wins now
- **Technology Benefit:** All bands, all data rates, 450m LOS, 45m NLOS
- **Productisation:** Production ready design

MPW2 July 2011
- **Customer Validation:** 10 customers endorse & request full production, will design with MPW2
- **Technology Benefit:** Proving design robustness and performance.
- **Productisation:** Full featured design with optimised analog front end

MPW1 May 2010
- **Customer Validation:** 2 way ranging & RTLS demo to LG Innotek, Gemalto & Continental
- **Technology Benefit:** full transceiver single chip integration, proving RF architecture
- **Productisation:** Proving cost profile

FPGA Prototype March 2009
- **Customer Validation:** Sold 45 kits to 17 customers
- **Technology Benefit:** Communications range and location precision demonstrated
- **Productisation:** Proving algorithms
Design methodology

Model   Prototype   MPW1   MPW2   MPW3

Synopsys
Typical Use Cases
Two-way ranging: TWR Versus SDS-TWR

Figure D1.5—Exchange of message in two-way ranging

\[ \Delta t_p = \frac{1}{2} \times t_{replyB} \times (e_A - e_B) \]

Table D1.1—Typical errors in time-of-flight estimation using TWR

<table>
<thead>
<tr>
<th>( t_{replyB} / (e_A - e_B) ) (( \mu s ))</th>
<th>2 ppm (ns)</th>
<th>40 ppm (ns)</th>
<th>80 ppm (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 ( \mu s )</td>
<td>0.1 ns</td>
<td>2 ns</td>
<td>4 ns</td>
</tr>
<tr>
<td>5 ( \mu s )</td>
<td>5 ns</td>
<td>100 ns</td>
<td>200 ns</td>
</tr>
</tbody>
</table>

Figure D1.6—Exchange of message in SDS-TWR

Table D1.2—Typical errors in time-of-flight estimation using SDS-TWR

<table>
<thead>
<tr>
<th>( \Delta t_{reply} / (e_A - e_B) ) (( \mu s ))</th>
<th>2 ppm (ns)</th>
<th>20 ppm (ns)</th>
<th>40 ppm (ns)</th>
<th>80 ppm (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0005</td>
<td>0.005</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>10</td>
<td>0.005</td>
<td>0.05</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>100</td>
<td>0.05</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Mobile Use Case: Proximity Location

- Accurate location relative to other enabled handsets
- Can achieve this without any other 802.15.4a infrastructure
- Location of mislaid personal or secure items and people

DecaWave enabled

Location accurately determined with 450m LOS range

DecaWave enabled

Tagged Wallet
Tagged Keys
Tagged Laptop
Tagged Child
Automotive Keyless / Passive Entry

- DecaWave technology can be used to implement secure keyless and passive entry schemes
- Using DecaWave chips in the vehicle and in the key fob, the location of the fob relative to the vehicle can be determined

- Based on this information, various actions can be taken
  - Relevant doors opened automatically
  - Driver / Passenger welcome messages
- It is very difficult to “hack” this scheme so it is far more resistant to “Relay Attack” than present schemes
- The operating frequencies of existing schemes are suffering more and more interference from new technology such as Smartphones and iPads – DecaWave’s technology resolves those issues
Time of Arrival Based Ranging

\[ \hat{d} = (\hat{t}_{RX} - t_{TX})c \]

Time of Flight: Trilateration

Time Difference of Arrival: Multilateration
Mobile Use Case: Service and Content

- Determine precise proximity to in-store detector nodes and use the information for location based services
- Requires deployment of 802.15.4a based in-store detectors

User Preference Database

Control Centre

Specific location related info

DecaWave enabled

Option to purchase audio tour / bus tour location aware software for certain locations (e.g. Art Galleries, Museums, etc)
Mobile Use Case: Healthcare

- Patient with DecaWave enabled wireless bio sensors
- Patient's Doctor with DecaWave enabled device
- Medical Equipment Tagged
- Patient's Carer with DecaWave enabled device

Hospital

Specific location related info

Mobile Network
Wireless Sensor Networks

Monitoring & Control Centre

Sensor Node

Routing Node

Sensor Node

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Sensor Node
Decawave’s market space
The Market Space

RTLS, WSN

INDUSTRIAL
Factory, Buildings, Enterprise, Agriculture, Healthcare, Warehousing, Safety & Security

AT HOME
Healthcare, Home Automation, Safety & Access,

WiFi, Mobility

Access Points, LBS, Enterprise

Portable Consumer, PC, Tablets

RETAIL, ePOS

Authentication, Customer Fidelity, Financial Services, LBS

Consumer
Portable Consumer
At home

Automotive
Secure Access, Communications
The Market: Focus Verticals and Horizontals

**Locating (RTLS)**
- WE FIX THE PRECISION PROBLEM
- WE ENABLE HIGHER TAG DENSITY
- WE FIX THE POWER CONSUMPTION PROBLEM
- WE ENABLE LOW COST TAGS

**Sensing (WSN)**
- WE FIX THE POWER CONSUMPTION ISSUE
- WE ENABLE HIGHER DATA RATES
- WE FIX THE MULTIPATH PROBLEM

**Verticals**
- Electronic Shelf Labelling
- HealthCare
- Safety / Security
- Agriculture
- Factory Automation
- Warehouse & Logistics
- Building Control
- Automotive
- Mobile Phone
Thank you very much!

• Contacts:
  • luc.darmon@decawave.com